

## EXHAUST GAS PURIFYING APPARATUS

### BACKGROUND OF THE INVENTION

The present invention relates to an exhaust gas purifying apparatus.

The present inventors have proposed Registered Japanese Utility Model No. 2593255 (hereinafter referred to as a first conventional example) as a purifying apparatus for purifying harmful exhaust gas discharged from a combustion apparatus such as an internal combustion engine, e.g., a diesel engine of an automotive vehicle, a ship and the like or a combustion apparatus such as garbage burning furnace, a boiler and the like.

The first conventional example is mounted on, for example, a muffler of an automotive vehicle to purify the exhaust gas. A liquid reservoir chamber reserving liquid catalyst (for example, water) and a solid catalyst chamber containing solid catalyst are provided in the interior of the first conventional example.

According to this first conventional example, the exhaust gas discharged from the engine is first introduced into the liquid reservoir chamber and caused to pass through the water so that the harmful substance contained in the above-described exhaust gas, for example, nitrogen oxide, black smoke or the like is removed. Subsequently, the exhaust gas is introduced into the solid catalyst chamber and caused to be brought into contact with the solid catalyst so that the harmful substance residing in the exhaust gas is removed.

Accordingly, a large amount of harmful substance has been removed from the exhaust gas discharged from the engine and thereafter is discharged to the atmosphere.

Patent Publication 1      Registered Japanese Utility Model No. 2593255

Patent Publication 2      Japanese Patent No. 2634563

However, the first conventional example suffers from such a problem that, due to the fact that the exhaust gas is discharged to the liquid reservoir chamber under the condition that the exhaust gas is kept at a high temperature, a temperature of the water within the liquid reservoir chamber is elevated as time lapses, as a result of which the liquid (water) is evaporated and discharged out of the liquid reservoir chamber.

For this reason, in the first conventional example, it is necessary to frequently replenish the water corresponding to the decrease of the water. In particular, the example is insufficient in

practical use in the case where the engine runs for a long period of time.

By the way, in order to overcome the above-noted defect to some extent, Japanese Patent No. 2634563 (hereinafter referred to as a second conventional example) has been proposed.

The second conventional example is constructed so that a cooling pipe (heat pipe) is provided in a liquid reservoir chamber and a replenishing reservoir is provided for replenishing water to a liquid reservoir chamber.

According to this second conventional example, even if the high temperature exhaust gas is discharged from, for example, the engine to the liquid reservoir chamber, the water within this liquid reservoir chamber is cooled down by the cooling pipe so that the temperature thereof is hardly elevated. Accordingly, it is possible to suppress the evaporation of the water of the liquid reservoir chamber to some extent. Furthermore, even if the water is evaporated, it is possible to replenish the water from the replenishing reservoir.

Accordingly, in the second conventional example, it is possible to continue purifying the exhaust gas for a long period of time in comparison with the first conventional example. Thus, it is possible to make, for example, the engine run for a long period of time.

However, even in the second conventional example, after all, if the water within the replenishing reservoir is decreased and in short supply, it is necessary to replenish the water. Accordingly, there is a limit to make the engine run for a long period of time.

## SUMMARY OF THE INVENTION

Accordingly, in view of the foregoing defects, an object of the present invention is to provide a novel exhaust gas purifying apparatus that may continue purifying exhaust gas without replenishing liquid catalyst to a liquid reservoir chamber for making, for example, an engine run for a long period of time and is superior in practical use.

The essence of the present invention will now be described with reference to the accompanying drawings.

According to a first aspect of the present invention, there is provided an exhaust gas purifying apparatus for purifying exhaust gas by bringing the exhaust gas into contact with liquid catalyst 1 and solid catalyst 2, comprising an apparatus body 3 having a liquid reservoir chamber 21 where liquid catalyst 1 is reserved, a solid catalyst chamber 22 where the solid catalyst 2 is

arranged and a cooling mechanism 4 for cooling the liquid catalyst 1, wherein said cooling mechanism 4 controls a temperature of the liquid catalyst 1 so that up-and-down shift of a liquid level of the liquid catalyst 1 in the liquid reservoir chamber 21 is prevented as much as possible.

According to a second aspect of the invention, there is provided an exhaust gas purifying apparatus for purifying exhaust gas by bringing the exhaust gas into contact with liquid catalyst 1 and solid catalyst 2, comprising an apparatus body 3 having a liquid reservoir chamber 21 where the liquid catalyst 1 is reserved, a solid catalyst chamber 22 where the solid catalyst 2 is arranged and a cooling mechanism 4 for maintaining the liquid catalyst 1 in the liquid reservoir chamber 21 to a temperature not higher than 50°C.

In the exhaust gas purifying apparatus according to the aspect 1 or 2 of the invention, according to a third aspect of the invention, the cooling mechanism 4 is adapted to keep the liquid catalyst 1 in the liquid reservoir chamber 21 in the range of 40 to 50°C as much as possible when the exhaust gas passes through the liquid reservoir chamber 21.

In the exhaust gas purifying apparatus according to any one of the first to third aspects of the invention, according to a fourth aspect of the invention, a cooler using at least one of a heat pipe, a fin or a cooling medium is used as the cooling mechanism 4.

In the exhaust gas purifying apparatus according to any one of the first to third aspects of the invention, according to a fifth aspect of the invention, a cooling device 33 that exhibits a cooling effect by a heat pipe and electric supply is used as the cooling mechanism 4.

In the exhaust gas purifying apparatus according to any one of the first to fifth aspects of the invention according to a sixth aspect of the invention, a solid catalyst chamber having such a structure that a plurality of partial chambers 5 are formed together, a solid catalyst plate 2 is provided in each partial chamber 5, and the exhaust gas passes through each partial chamber 5 in order and is in contact with the solid catalyst plate 2 of each partial chamber 5 is used as said solid catalyst chamber 22.

In the exhaust gas purifying apparatus according to the sixth aspect of the invention, according to a seventh aspect of the invention, at least two solid catalyst plates 2 are provided in each partial chamber 5.

According to an eight aspect of the invention, there is provided an exhaust gas purifying apparatus for purifying exhaust gas by bringing the exhaust gas into contact with liquid catalyst 1

and solid catalyst 2, comprising an apparatus body 3 having a liquid reservoir chamber 21 where the liquid catalyst 1 is reserved and a solid catalyst chamber 22 where the solid catalyst 2 is arranged, wherein said solid catalyst chamber 22 is composed of a plurality of partial chambers 5 together, at least two solid catalyst plates 2 are provided in each partial chamber 5, and the exhaust gas passes through each partial chamber 5 in order and is in contact with the solid catalyst plates 2 of each partial chamber 5.

In the exhaust gas purifying apparatus according to any one of first through eighth aspects of the invention, according to a ninth aspect of the invention, an introduction portion 6 for introducing the exhaust gas to the liquid catalyst 1, and an atomizing mechanism for atomizing the exhaust gas introduced into the liquid reservoir chamber 21 from the introduction portion 6 are provided in the liquid reservoir chamber 21.

In the exhaust gas purifying apparatus according to the ninth aspect of the invention, according to a tenth aspect of the invention, an atomizing mechanism where the exhaust gas passing through a member 16 provided with a plurality of small holes juxtaposed in an up-and-down direction of the liquid reservoir chamber 21 and atomized by the small holes is used as said atomizing mechanism.

With such an arrangement of the present invention, it is possible to provide an exhaust purifying apparatus that is superior in practical use and may continue purifying the exhaust gas well for a long period of time without replenishing the liquid catalyst to the liquid reservoir chamber.

#### BEST MODE OF THE INVENTION

The best mode of embodying the invention and its resultant effect will now be described in brief with reference to the accompanying drawings.

The exhaust gas is caused to pass through the liquid reservoir chamber 21 and the solid catalyst chamber 22 so that a large amount of harmful substance contained in the exhaust gas is removed by the liquid catalyst 1 (for example, water) and the solid catalyst 2 to thereby purify the exhaust gas.

Because the exhaust gas is kept at a high temperature when the exhaust gas is caused to pass the liquid reservoir chamber 21, the temperature of the liquid catalyst 1 within the liquid

reservoir chamber 21 is like to become high.

In this case, the temperature of the liquid catalyst 1 is controlled by the cooling mechanism 4 whereby the up-and-down shift of the liquid level of the liquid catalyst 1 within the liquid reservoir chamber 21 is prevented as much as possible.

More specifically, the exhaust gas discharged from the internal combustion engine or the like is kept at a high temperature as described above. Accordingly, when the exhaust gas is introduced into the liquid reservoir chamber 21, the temperature of the liquid catalyst 1 is raised due to the time lapse. In this case, the cooling mechanism 4 controls the temperature of the liquid catalyst 1 within the liquid reservoir chamber 21 so as to be not higher than a predetermined temperature and to prevent the liquid level of the liquid catalyst 1 from lowering due to the evaporation of the liquid catalyst by the elevation of the temperature of the liquid catalyst 1.

However, if the moisture contained in the exhaust gas, i.e., the moisture generated due to the combustion of fuel in the internal combustion engine, for example, is dewed within the liquid reservoir chamber 21, the liquid level of the liquid catalyst 1 is raised. In this respect, the cooling mechanism 4 according to the invention does not more cool the liquid catalyst 1 than necessary. It is thus possible to prevent the liquid level due to such dew.

With such an arrangement of the present invention, it is possible to provide an exhaust purifying apparatus that is superior in practical use and may continue purifying the exhaust gas well for a long period of time without replenishing the liquid catalyst to the liquid reservoir chamber.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic perspective view of an apparatus according to an embodiment.

Fig. 2 is a schematic side elevation sectional view showing half a front side (foreside) of the apparatus body shown in Fig. 1.

Fig. 3 is a schematic side elevation sectional view showing half a back side (rear side) of the apparatus body shown in Fig. 1.

Fig. 4 is a partially enlarged, side elevational sectional view showing a portion where a small hole provided member is provided in a liquid reservoir chamber.

Fig. 5 is an illustration of the apparatus according to the embodiment in use.

Fig. 6 is a schematic perspective view showing another example of a cooling mechanism according to this embodiment.

Fig. 7 is a schematic perspective view showing still another example of a cooling mechanism according to this embodiment.

Fig. 8 is a schematic perspective view showing still another example of a cooling mechanism according to this embodiment.

Fig. 9 is a schematic perspective view showing still another example of a cooling mechanism according to this embodiment.

### PREFERRED EMBODIMENTS OF THE INVENTION

The present invention will now be described in more detail with reference to the accompanying drawings.

According to this embodiment, exhaust gas is brought into contact with liquid catalyst, more specifically, water 1 and solid catalyst 2 to thereby purify the exhaust gas. The apparatus is constructed so that a liquid reservoir chamber 21 reserving therein water 1 and a solid catalyst chamber 22 where solid catalyst plates 2 are arranged are provided in an apparatus body 3, and furthermore, a cooling mechanism 4 for cooling water 1 is provided in the liquid reservoir chamber 21.

In the apparatus body 3, an introduction portion 6 for introducing the exhaust gas from an internal combustion engine or the like into the apparatus body 3 is provided at one end portion (right end portion) of the apparatus body 3 in the right and left direction (longitudinal direction) of Figs. 2 and 3.

On the other hand, a discharge portion 12 for discharging the exhaust gas from the interior to the exterior of the apparatus body 3 is provided at the other end portion (left end portion) of the apparatus body 3 in the right and left direction (longitudinal direction) of Figs. 2 and 3.

Namely, the apparatus body 3 is constructed in such a manner that the exhaust gas is introduced from the introduction portion 6 to the interior of the apparatus body 3 and discharged from a discharge portion 12 to the outside of the apparatus body 3.

Also, the apparatus body 3 is partitioned into upper and lower layers by a partitioning

plate 25 so that the lower layer is set for the liquid reservoir chamber 21 and the upper layer is set for the solid catalyst chamber 22.

A communication hole 11 is formed in the partitioning plate 25 whereby the liquid reservoir chamber 21 and the solid catalyst chamber 22 are in communication with each other.

An overflow cock 13 is provided for pouring water 1 into the liquid reservoir chamber 21 and discharging water 1 outside the apparatus body 3 over a predetermined level when water 1 is reserved over the predetermined level within the liquid reservoir chamber 21.

A drain bolt 14 is provided in a bottom surface portion of the liquid reservoir chamber 21 for replacing water 1. Incidentally, this drain bolt 14 is used when harmful substance contained in the exhaust gas and accumulated on the bottom portion of the liquid reservoir chamber 21 is discharged together with water 1.

The introduction portion 6 is constituted by an introduction pipe 6B. A tip end of this introduction pipe 6B, i.e., an introduction inlet 6A through which the exhaust gas is introduced into water 1 is provided close to the bottom surface of the liquid reservoir chamber 21 so as to cause the exhaust gas to sufficiently pass through water 1.

It is preferable to provide an atomizing mechanism for atomizing the exhaust gas introduced from the introduction inlet 6A of the introduction pipe 6B into water 1 as shown in Fig. 4. For example, it is preferable to use porous material 16 (meshes 16) as the atomizing mechanism. In this case, it is preferable to use a plurality of meshes (for example, three meshes as Fig. 4) disposed at predetermined intervals in the up-and-down direction in the water 1 within the liquid reservoir chamber 21 in order to well perform the atomization of the exhaust gas.

Also, in Fig. 4, zigzag waved meshes 16 are used as the meshes 16 for the purpose of effectively atomizing the exhaust gas and causing the exhaust gas to be in contact with the water 1 for a long period of time. However, it is possible to simply use flat meshes.

The water 1 is filled up to a predetermined level within the liquid reservoir chamber 21.

Heat pipes 4 are used as a cooling mechanism 4.

A plurality (four in Figs. 1 to 3) of heat pipes 4 are juxtaposed in the right and left direction (the exhaust gas flow direction) of the liquid reservoir chamber 21 of Figs. 2 and 3.

More specifically, each heat pipe 4 is inserted from one side surface into the liquid reservoir chamber 21 in a direction from a front surface to a back surface of the liquid reservoir

chamber 21 (widthwise direction) of Figs. 2 and 3.

Also, the heat pipe 4 is constructed so that the up-and-down shift of the liquid level of the water 1 is prevented as much as possible when the exhaust gas is introduced into the water.

Furthermore, more specifically, the heat pipe 4 is constructed so that the temperature of the water 1 is kept in the range of 40°C to 50°C upon the introduction of the exhaust gas as much as possible.

A sleeve member 9 (for example, sleeve member made of punched metal) that may purge the gas in communication with the communication hole 11 is provided vertically on the lower side of the communication hole 11.

A solid catalyst plate 2 that has a larger diameter than a diameter of the sleeve member 9 is provided horizontally at the lower end of the sleeve member 9.

A number of small communication holes in communication with the sleeve member 9 are formed in the solid catalyst plate 2.

Another (second) solid catalyst plate 2 having the similar shape to the solid catalyst plate 2 is arranged below the first solid catalyst 2, provided on the sleeve member 9, at a predetermined interval under the condition that the second solid catalyst 2 covers the first solid catalyst plate 2.

The exhaust gas that has passed through the water 1 within the liquid reservoir chamber 21 moves along an outer surface of the second (outer) solid catalyst plate 2 and is introduced into the sleeve member 9 made of punched metal. Also, the exhaust gas moves through the interval between the first (inner) solid catalyst plate 2 and the second (outer) solid catalyst plate 2 and is introduced into the sleeve member 9 through the communication holes formed in the first solid catalyst plate 2. The exhaust gas that has been introduced into the sleeve member 9 is further introduced into the solid catalyst chamber 22 through the communication hole 11.

The solid catalyst chamber 22 is provided in the upper layer of the apparatus body 3 as described above, and is constructed so that a plurality of partial chambers 5 formed substantially in the same way are provided adjacent to each other in the right and left direction. In case of Figs. 2 and 3, four partial chambers and two partial chambers are arranged in the right and left direction and the front and back direction (back and forth), respectively, and the eight partial chambers are arranged in total. Each partial chamber 5 is partitioned by a partition 7.

The plurality of partial chambers 5 are in communication with each other through a



passage 10 for communicating an upper portion of each partial chamber 5 with a lower portion of the partial chamber 5 adjacent to this partial chamber 5 in the right and left direction (longitudinal direction). Furthermore, the rightmost partial chamber of Fig. 2 and the rightmost partial chamber of Fig. 3 are in communication with each other through the communication hole provided in the lower portion of the partition 7 positioned therebetween.

In Fig. 3, the passage 10 is formed by locating the passage in the lower portion by the upper end of the partition 7 of the rightmost partial chamber 5 and by locating the passage above the bottom plate of the solid catalyst chamber 22 and the lower end of the partition 7 of the adjacent partial chamber 5. Incidentally, the passage for communicating other partial chambers 5 with each other has substantially the same structure.

Also, each partial chamber 5 is partitioned into small partial chambers 5A layered in three-stages by lateral partitions 30.

An insertion hole 8 is provided in the middle portions of the lateral partitions 30 for passage of the exhaust gas in the up-and-down direction (specifically from the lower side to the upper side).

A sleeve member 28 (for example, punched metal made sleeve 28) is provided vertically above the insertion hole 8 for purging the exhaust gas.

The solid catalyst plate 2 that has a larger diameter than a diameter of the sleeve member 28 is provided horizontally at the upper end of the sleeve member 28.

Also, a number of small communication holes in communication with the sleeve member 28 are formed in the solid catalyst plate 2.

Another (second) solid catalyst plate 2 having the similar shape to the solid catalyst plate 2 is arranged above the first solid catalyst plate 2, provided on the sleeve member 28, at a predetermined interval under the condition that the second solid catalyst 2 covers the first solid catalyst plate 2.

Incidentally, neither sleeve member 28 nor the solid catalyst plate 2 is provided in the small partial chamber 5A adjacent to the discharge portion 12. Only an introduction sleeve 32 is provided for introducing the exhaust gas from the lower small partial chamber 5A to this small partial chamber 5A.

A structure obtained by plating or evaporating copper, silver, platinum, palladium,

rhodium or the like on a mesh member made of iron, stainless steel or the like or a mesh member made of aluminum may be used as the solid catalyst plate 2. The mesh holes of the mesh means the above-described small communication holes. Incidentally, it is possible to suitably use other catalyst other than the above-listed substances if the catalyst may remove the harmful substance contained in the exhaust gas.

Also, as shown in Figs. 2 and 3, the solid catalyst plate 2 is formed into a labyrinth structure by folding back the edge portions after extending the edge portions downwardly.

With such an arrangement, when the exhaust gas is introduced from the internal combustion engine or the like through the introduction portion 6 into the liquid reservoir chamber 21, the exhaust gas is caused to pass through the water 1 and the exhaust gas and the water 1 are brought into contact with each other so that the harmful substance contained in the exhaust gas (harmful substance soluble in water) is removed.

Subsequently, the exhaust gas is introduced into the small partial chambers 5A forming the solid catalyst chamber 22 through the communication hole 11, and is brought into contact with the solid catalyst plate 2 arranged within the small partial chambers 5A. In this case, the exhaust gas reacts with the solid catalyst plates 2 to thereby further remove the harmful substance from the exhaust gas.

Then, the exhaust gas from which the harmful substance has been removed is discharged from the discharge portion 12 to the outside of the apparatus body 3.

Thus, the exhaust gas introduced from the introduction portion 6 into the interior of the apparatus body 3 is discharged from the discharge portion 12 to the outside of the apparatus body 3 after almost all the harmful substance contained in the exhaust gas has been removed.

Also, the temperature of the water 1 within the liquid reservoir chamber 21 is elevated because the exhaust gas is kept at a high temperature when the exhaust gas is introduced into the liquid reservoir chamber 21. However, there is no fear that the temperature of the water 1 would be elevated higher than necessary because the temperature of the water 1 is controlled at a level not higher than 50°C by the cooling effect of the heat pipes 4 provided within the liquid reservoir chamber 21. It is thus possible to prevent the evaporation of the water 1 and the decrease of the liquid level of the water 1.

Also, the temperature of the water 1 is controlled so that it is not lower than 40°C by the

cooling effect of the heat pipes 4. As a result, there is no fear that the liquid reservoir chamber 21 would be cooled down to a temperature than necessary. It is thus possible to prevent the liquid level of the water 1 from elevating due to the fact that the moisture contained in the exhaust gas (moisture formed by combustion of the fuel) dews within the liquid reservoir chamber 21.

Namely, in this embodiment, the temperature of the water between 40°C and 50°C that may be controlled by the cooling effect of the heat pipes 4 is a temperature at which the amount of the liquid decreased by the evaporation of the water 1 due to the age change and the amount of the water contained in the exhaust gas and to be introduced into the liquid reservoir chamber 21 may be kept just in an equilibrium. Thus, it is possible to prevent the up-and-down shift of the liquid level of the water 1 within the liquid reservoir chamber 21 as much as possible.

Also, the porous member 16 (mesh 16) that is the atomizing mechanism is present in the liquid reservoir chamber 21 so that the exhaust gas introduced into the liquid reservoir chamber 21 through the introduction portion 6 is atomized in a fine bubble state in contact with the mesh member 16 within the water 1. As a result, the specific surface area of the exhaust gas within the water 1 is increased whereby the exhaust gas may come into contact with the water 1 in a good condition. Furthermore, the exhaust gas is caused not to simply pass the mesh member 16 due to the zigzag waved shape of the mesh member but to shift upward along the slant surface of the zigzag waved mesh member 16 while taking time to thereby further atomizing the exhaust gas into a bubble state and to make it possible to contact the exhaust gas with the water 1 more effectively to thereby remove the more harmful substance that is soluble in the water 1 from the exhaust gas.

Also, the exhaust gas is atomized and brought into contact with the water 1 under the condition that the exhaust gas is atomized while taking time whereby it is possible to react the exhaust gas and the water 1 with each other to remove the smoke contained in the exhaust gas more effectively.

Also, when the exhaust gas is introduced from the liquid reservoir chamber 21 through the communication hole 11 into the solid catalyst chamber 22, the exhaust gas is introduced into the small partial chamber 5A adjacent to the communication hole 11, brought into contact with the inner side surface (lower surface) of the lower solid catalyst plate 2 out of the two solid catalyst plates 2 arranged up and down in the small partial chamber 5A and shifted toward the edge

portion of the solid catalyst plate 2 along the inner side surface (lower surface) of the solid catalyst plate 2.

In this case, the exhaust gas and the solid catalyst plate 2 are brought into contact and react with each other to thereby decompose and remove the harmful substance contained in the exhaust gas.

Furthermore, subsequently, the exhaust gas that has reached the outer edge portion of the lower solid catalyst plate 2 shifts toward the upper central portion of the solid catalyst plate 2 along the outer side surface (side surface and upper surface) of the upper solid catalyst plate 2.

Also in this case, the harmful substance residing in the exhaust gas reacts with the solid catalyst plates 2 so that the harmful substance is removed.

Also, the exhaust gas is introduced between the upper solid catalyst plate 2 and lower solid catalyst plate 2 so that the exhaust gas reacts with the solid catalyst plates 2 to thereby remove the harmful substance.

Then, the exhaust gas is introduced from the communication hole 8 provided in the upper small partial chamber 5A to the upper small partial chamber 5A.

With such an arrangement of this embodiment, it is possible to well purify the exhaust gas for a long period of time. Namely, not only can the harmful substance contained in the exhaust gas be decomposed and positively removed by the solid catalyst plates 2 within the solid catalyst chamber 22 and the water 1 within the liquid reservoir chamber 21 but also it is possible to suppress the up-and-down shift of the liquid level of the water because the water 1 is controlled in the range of the temperature between 40°C and 50°C by the cooling effect of the heat pipes 4 provided within the liquid reservoir chamber 21 so that the amount of decrease of the water 1 due to the evaporation and the amount of increase of the water contained in the exhaust gas and to be introduced into the liquid reservoir chamber 21 and dewed may be kept in the equilibrium. Thus, it is possible to suppress the up-and-down shift of the liquid level of the water 1, so that it is unnecessary to replenish the water 1 to the liquid reservoir chamber 21 and there is no fear that the water 1 is overflowed. It is thus possible to continue to purify the exhaust gas for a long period of time and to cause, for example, the engine to run for a long period of time.

Also, the mesh 16 is provided as the atomizing mechanism in the liquid reservoir chamber 21 so that the exhaust gas to be introduced into the liquid reservoir chamber 21 may be

formed into the fine bubble state in the water 1. Furthermore, the mesh 16 is formed into the zigzag waveform so that the exhaust gas is caused to pass through the mesh 16 while taking time, thereby making it possible to bring the exhaust gas into a finer bubble state in contact with the water 1 with a larger contact surface area to thereby make it possible to remove the large amount of harmful substance more effectively. In this case, particularly, the smoke may be removed from the exhaust gas.

Also, the solid catalyst chamber 22 is composed of a large number of small partial chambers 5A and two solid catalyst plates 2 are provided in each small partial chamber 5A. As a result, the exhaust gas may be brought into contact with the solid catalyst plates 2 with a larger contact area so that the harmful substance may be removed from the exhaust gas much more effectively.

Furthermore, the shape of the solid catalyst plates 2 is formed into the labyrinth structure so that the contact area between the exhaust gas and the solid catalyst plates 2 may be increased and the contact time may be elongated. Thus, the exhaust gas may be brought into contact with the solid catalyst plate 2 much more effectively to thereby make it possible to remove the harmful substance contained in the exhaust gas more effectively and positively.

Incidentally, in this embodiment, the mesh 16 is used as the atomizing mechanism. However, a plurality of fine purging holes may be provided on an outer circumferential portion of the introduction pipe serving as the introduction portion so that the exhaust gas may be introduced into the water from the plurality of purging holes and may be atomized.

Also, in this case, it is possible to adopt such a structure that the introduction port at the tip end of the introduction pipe is covered by a fine mesh to thereby well atomize also the exhaust gas introduced from the introduction port. In this case, it is preferable that a larger portion of the introduction pipe be dipped into the water.

Also, it is possible to adopt such a structure that a porous stone that is formed into a rod shape is connected to the introduction pipe and the exhaust gas is introduced through the porous stone for atomizing and introducing the exhaust gas into the water within the liquid reservoir chamber 21. In this case, it is preferable that a longitudinal hole having a predetermined depth in terms of a cross sectional area of the stone formed into the rod shape is formed in the longitudinal direction of the porous stone and the introduction pipe is inserted into this longitudinal hole to

thereby introduce the exhaust gas into the longitudinal hole. (It should be noted that the introduction pipe provided around the circumferential portion with the number of the purging holes is used preferably.) Thus, the exhaust gas is atomized and introduced into the water through the porous stone.

Also, in this embodiment, the two solid catalyst plates 2 are provided in each small partial chamber 5A. However, it is also possible to use three or more solid catalyst plates for each small partial chamber 5A.

Figs. 6 to 9 show another example of the cooling mechanism 4.

In Fig. 6, fins 15 (heat radiating plates) are provided around an outer surface portion of the liquid reservoir chamber, and the water within the liquid reservoir chamber is cooled down by the cooling effect of the fins 15.

According to this example shown in Fig. 6, since a plurality of fins 15 are simply provided on the outer surface portion of the liquid reservoir chamber to thereby form the cooling mechanism 4. It is thus possible to form the cooling mechanism 4 with ease and in low cost.

In Fig. 7, the water within the liquid reservoir chamber is transferred to the radiator 17 provided outside the liquid reservoir chamber by using a recirculation pump 18, the heat of the water is radiated by the radiating effect (cooling effect) of the radiator 17 and the water 1 from which the heat has been removed is returned back again to the liquid reservoir chamber to thereby cool the water.

In this example shown in Fig. 7, since it is possible to transfer the water per se within the liquid reservoir chamber to the radiator 17 outside the apparatus body 3 and to radiate the heat, the heat of the water may be radiated and the water is cooled down more effectively. Also, the water is transferred to the radiator 17 and the water is returned back again to the liquid reservoir chamber from the radiator 17 to thereby circulate the water so that the water takes convection within the liquid reservoir chamber to thereby keep the water at the predetermined liquid level more effectively.

In Fig. 8, there is shown such a cooling mechanism 4 that a recirculation route 29 is provided for recirculation between the inside of the liquid reservoir chamber and the outside of the liquid reservoir chamber, coolant is filled in the recirculation route 29, and the coolant is used for heat exchange between the inside of the liquid reservoir chamber and the outside of the liquid

reservoir chamber to exhibit the cooling effect of the water within the liquid reservoir chamber.

A condenser 23 for forcibly cooling the coolant passing through the recirculation route 29 is provided outside the liquid reservoir chamber in the recirculation route 29. The coolant is condensed down to a suitable temperature by the control of the condenser 23 to thereby make it possible to control the water within the liquid reservoir chamber to a suitable temperature.

In this cooling mechanism 4, more specifically, an evaporator 19 is provided in the liquid reservoir chamber, the condenser 23 is provided outside the liquid reservoir chamber, an expansion valve 24 is provided on the coolant introduction side from the condenser 23 to the evaporator 19 and between the evaporator 19 and the condenser 23, and a compressor 20 is provided on the side of the discharge side of the coolant from the evaporator 19 to the condenser 23 and between the evaporator 19 and the condenser 23. With such an arrangement, the coolant that has absorbed the heat from the water in the evaporator 19 and has been gasified is compressed by the compressor 20, the coolant kept at a high temperature is further cooled down by the condenser 23 to be liquefied, thereafter, the pressure is decreased in the expansion valve 24 and the coolant is again fed to the evaporator 19.

In the example shown in Fig. 8, it is possible to cool the water within the liquid reservoir chamber simply by passing the specialized coolant through the evaporator 19. Also, it is possible to precisely control the temperature of the coolant by the degree of condensation of the specialized coolant by the condenser 23 or the degree of compression of the specialized coolant by the compressor 20.

Accordingly, in the example shown in Fig. 8, it is possible to very precisely control the temperature of the water in the liquid reservoir chamber in comparison with the other example, to thereby make it possible to prevent the up-and-down shift of the liquid level of the water without fail.

Fig. 9 shows a cooling device 33 for exhibiting the cooling effect of a plurality of heat pipes 27, arranged in the liquid reservoir chamber 21, by supplying electricity to the heat pipes 27. The plurality of heat pipes 27 are juxtaposed at an interval in the longitudinal direction of the apparatus body 3 (in the liquid reservoir chamber 21) so as to project at one end portions outside the apparatus body 3 as shown in Fig. 1.

The cooling device 33 is an electronic cooling device using a Peltier element that

generates a temperature difference between top and bottom by the electric supply.

More specifically, as shown in Fig. 9, an aluminum block 37 is provided at the end portion of the heat pipe 27 projecting outside of the apparatus body 3 (the liquid reservoir chamber 21) from the interior of the apparatus body 3, and an element portion 34 in which the Peltier element is built is provided on the aluminum block 37.

A radiator 35 for radiating the heat of the element portion 34 is provided on the element portion 34.

Then, a blower 36 is provided on the radiator 35 for accelerating the radiation of the radiator 35.

Incidentally, in this embodiment, the heat pipe 27 and the element portion 34 are provided together through the aluminum block 37. However, it is possible to provide the element portion 34 directly to the heat pipe 27 without using the aluminum block 37.

Also, in this embodiment, the electronic cooling device using the Peltier element is used as the cooling device 33. However, if the device may exhibit the same effect as that of this embodiment, it is possible to use any device other than the Peltier element.

In this cooling device 33, the temperature control of the water within the liquid reservoir chamber 21 may be performed through the heat pipe 27 by adjusting the operation of the blower 36, the element portion 34 or the radiator 35.

In Fig. 9, the heat absorbed from the liquid reservoir chamber by the heat pipe 27 is transferred to the end portion of the heat pipe 27 and the heat is transferred to the element portion 34 through the aluminum block 37.

In this case, the element portion 34 kept under the electric supply condition becomes the condition that the side of the aluminum block 37 is cooled to thereby cool the heat pipe 27.

Also, the heat absorbed from the heat pipe 27 is transferred to the opposite side of the element portion 34, namely, the side of the radiator 35 and radiated by the radiator 35.

In this case, since the blower 36 for cooling the radiator 35 by blowing air thereto is provided on the radiator 35, the radiator 35 is cooled down by the blower 36 so that the cooling effect of the element portion 34 may be exhibited more effectively.

Accordingly, the cooling mechanism 4 shown in Fig. 9 becomes such a novel cooling mechanism 4 that it is possible to cool (radiate) the heat of the heat pipe 27 by using the Peltier



element that generates the temperature difference between top and bottom by the electric supply, thereby cooling down the liquid catalyst 1 (water 1) within the liquid reservoir chamber 21, also, the heat absorbed by the Peltier element is radiated by the radiator 35 so that it is possible to exhibit the effect of the Peltier element effectively, and furthermore, since the blower 36 is provided on the radiator 35 for accelerating the radiation, the effect of the Peltier element may be exhibited more effectively and the liquid catalyst 1 within the liquid reservoir chamber 21 may be continuously cooled down in the predetermined temperature range.

As described above, also, in the examples shown in Figs. 6 to 9, it is possible to exhibit the similar effect as that of the forgoing embodiment.

The experimental examples by which the specific effect of the embodiment was confirmed are shown as follows.

#### First Experimental Example

In the first experimental example, the experiments were conducted concerning the temperature change of the water 1 within the liquid reservoir chamber 21 by the cooling effect of the cooling device 4 shown in Fig. 8, that is, the cooling device 4 using the liquid coolant and the change of increase and decrease in the amount of the water 1 according to the temperature change.

The date of the experiments is June 12, 2002. The weather was fine and the temperature was 24.5°C and the wind was a breeze.

Also, the measurement had been conducted from 17:05 to 18:05 in the afternoon.

Also, the experiments were conducted by using a Japanese car and the RPM of the engine was set between 1,500 to 2,000 rpm.

First of all, when the cooling effect of the cooling device 4 was set at maximum and the experiments were conducted, the temperature of the water 1 that was 7.2°C before the start of the experiments had been elevated upon the lapse of time, the temperature was 34.2°C after the lapse of time, 30 minutes, after the start of the experiments, and the temperature had been kept and stayed thereafter.

In this case, the moisture contained in the exhaust gas was dewed in the liquid reservoir chamber 21 and the amount of water 1 was increased.

On the other hand, when the experiments were conducted while the cooling effect of the cooling device 4 was adjusted so that the temperature of the water 1 had been kept at about 55°C,

the amount of water 1 evaporated was greater than the amount of moisture introduced into the liquid reservoir chamber 21 by the combustion of fuel, and the amount of water 1 was decreased.

Then, the cooling device 4 was adjusted so that the temperature of water 1 was at 45°C, there was neither increase nor decrease of the amount of water 1.

From the foregoing experiments, it was found that it was preferable that not only was prevented the evaporation merely by cooling the water 1 but also the up-and-down shift of the water level was prevented as much as possible by controlling the cooling, and the temperature of water 1 was set at about 45°C (40°C to 50°C) in order to prevent the up-and-down shift of the water level.

Thus, according to the first experimental example, it was confirmed that the exhaust gas might be continuously purified in a good condition for a long period of time by the water and the solid catalyst plates without replenishing the water to the liquid reservoir chamber.

#### Second Experimental Example

The second experimental example was conducted as to how much the exhaust gas that had passed through the apparatus body 3 and had been discharged from the discharge portion 12 of the apparatus body 3 was purified. Incidentally, the experiments were committed to an incorporated foundation, Japan Automotive Transport Technology Association.

The experiments for the second experimental example were conducted for the case where the exhaust gas purifying device was not provided, for the case where the exhaust gas purifying device described in registered Japanese Utility Model No. 2,593,255 exemplified as a conventional technology was provided and for the case where the exhaust gas purifying apparatus according to the embodiment was provided.

Also, in the second experimental example, the exhaust smoke condensation of the smoke contained in the exhaust gas during the acceleration operation without any load was measured by passing the exhaust gas to a filter paper for a predetermined period of time.

Also, the experiments were conducted three times.

Incidentally, the measurement instruments used for the second experimental example were as follows:

Chassis Dynamo Meter (Model No. ZA-018 made by Kabushiki Kaisha Ono Sokuteiki)

Exhaust Gas Analyzer (Model No. MEXA-8120D made by Horiba Seisakusho)

Fuel Flow Rate Detector and Flow Rate Accumulator (Model No. FP214 DF314 made by Kabushiki Kaisha Ono Sokuteiki), and

Exhaust Gas Smoke Measurement Device (Model No. GSM-2 made by Yaei Kogyo Kabushiki Kaisha).

According to the second experimental example, in the case where the exhaust gas purifying apparatus was not provided, the exhaust gas smoke concentration was 21% first time, also 21% second time and 22% third time.

Thus, in the case where the exhaust gas purifying apparatus was not provided, a rather large amount of smoke (mainly black lead) was discharged to the atmosphere.

On the other hand, in the case where the exhaust gas purifying apparatus described in the registered Japanese Utility Model No. 2,593,255 was provided, the exhaust gas smoke concentration measured was 2% through first to third times. Namely, it was confirmed that if the exhaust gas purifying apparatus described in the registered Japanese Utility Model No. 2,593,255 was provided, a large amount of smoke contained in the exhaust gas might be removed but the smoke was not completely removed.

Also, in the case where the exhaust gas purifying apparatus according to this embodiment was provided, the measured exhaust gas smoke concentration was 0% through first to third times.

Thus, it was confirmed that if the exhaust gas purifying apparatus according to this embodiment was provided, the smoke might be completely removed from the exhaust gas.

In addition to the complete removal of the smoke, it was confirmed that the various kinds of substance might be well removed (or decomposed).

Accordingly, from the results of the first and second experimental examples, it was confirmed that the exhaust gas purifying apparatus according to this embodiment was a novel exhaust purifying apparatus that may continue the purification of the exhaust gas for a long period of time because it is unnecessary to replenish the water whereby the internal combustion engine such as an engine may continuously run for a long period of time and that may remove almost all harmful substance such as smoke contained in the exhaust gas.

Incidentally, the present invention is not limited to the specific embodiment shown but a specific structure of each constituent may be changed suitably in its design.